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Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Colorado, 1970. Part II

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The report presents the findings of the September 1970 environmental radiation study conducted in the environs of the Rocky Flats Plutonium Plant (Near Golden, Colorado). The field study and subsequent laboratory analyses were conducted by the staff of the Radiological Activities Section, Division of Technical Support, Water Quality Office, Environmental Protection Agency, Cincinnati, Ohio (an organizational unit of the Federal Water Quality Administration at the time of the study; reorganized into EPA in December 1971). Due to personnel transfers and changes in program responsibilities, a report on the study was not completed by the Radiological Activities Section prior to its dissolution from the EPA organizational structure during the first half of 1973. Since the primary investigators are now members of the Technical Investigations Branch, Surveillance and Analysis Division, and the environmental impact of the Rocky Flats Plant is a Region VIII concern, publication is undertaken as a regional responsibility.

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FOREWORD

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INTRODUCTION

During the week of February 20, 1970, representatives of the Federal Water Quality Administration visited the Rocky Flats Plant of the Atomic Energy Commission (located approximately 21 miles northwest of Denver, Colorado, between Golden and Boulder). The purpose of the visit was to obtain information on liquid radioactive waste management practices at the facility and the environmental surveillance activities in the plant environs. Coincidently with the site visit, limited water and bottom sediment sampling was conducted to obtain independent data on plutonium levels in surface waters receiving drainage (liquid wastes and land runoff) from the site and in other nearby lakes. The findings of the investigation were reported previously in 1971.(1)

As a follow-up to the February 1970 investigation, an intensive field study was conducted during the period of September 21-25, 1970. The basic objectives were to determine plutonium levels in the resident biota of Great Western Reservoir and Standley Lake and the overall distribution of plutonium in the bottom sediment of Great Western Reservoir. At least to the date of the study, off-site surveillance by the plant contractor, Dow Chemical Company, was limited to water and soil sampling; plutonium in aquatic biota was a monitoring void. Stations on Walnut Creek and Woman Creek, including Mower Reservoir, were revisited to obtain additional data on plutonium in bottom sediment and document changes which had occurred in the intervening seven month period.

By virtue of the fact that this report presents the findings of the September 1970 study, it constitutes a supplement to the previous April 1971 report.

SAMPLING PROCEDURES

Sampling stations for water, benthic organisms (benthos), and bottom sediment are listed in TABLE I and shown in FIGURES I-III. With the exception of sediment and benthos collection stations on Great Western Reservoir and Standley Lake, the sampling locations were identical to those established during the February 1970 study. As noted in the preceding section, all samples were collected during the period of September 21-25.

Water sampling was limited to three stations (TABLE I) with a daily grab sample (approx. 4 liters) collected at each station throughout the study period. It was assumed that samples collected from the shallow water at the dam faces were representative of the raw water pumped to the treatment plants serving the cities of Broomfield (Great Western Reservoir) and Westminster (Standley Lake). Uranium and plutonium analyses were conducted on composite (3 or 5 days) or the separate grab samples.

Bottom sediment samples were collected from Great Western Reservoir and Standley Lake (FIGURES II and III) with dredges, Petersen or Eckman, and a core sampler. At all other stations (creeks or impoundments), sediment samples were collected by scraping the bottom area below the water line with a hand trowel. The use of the hand trowel probably produced samples more representative of a thinner surface layer than those obtained with a dredge, particularly the Petersen dredge. Similar to the collection of sediment samples, benthos samples were collected with dredges. These samples were sieved in the field using a U.S. Standard No. 30 sieve. All material retained on the sieve was preserved in a 5% formalin solution for subsequent sorting and identification of the invertebrates and plutonium analysis.

Fish samples were collected with electro-fishing equipment from the shallow water areas near the dam and inlet of both Great Western Reservoir and Standley Lake. The fish were placed on ice immediately after collection and maintained in a frozen state until processed for plutonium analysis. A list of the species collected from each area is presented in TABLE II.

Soil samples were collected at two of the three stations previously sampled in February.

(1) Grazed area just to the southeast of the road culvert conveying Woman Creek under Indiana Street.

(2) Ungrazed area near the southeast corner of Great Western Reservoir.

These samples were collected with a hand trowel to a depth of 1/8-1/4 inches.

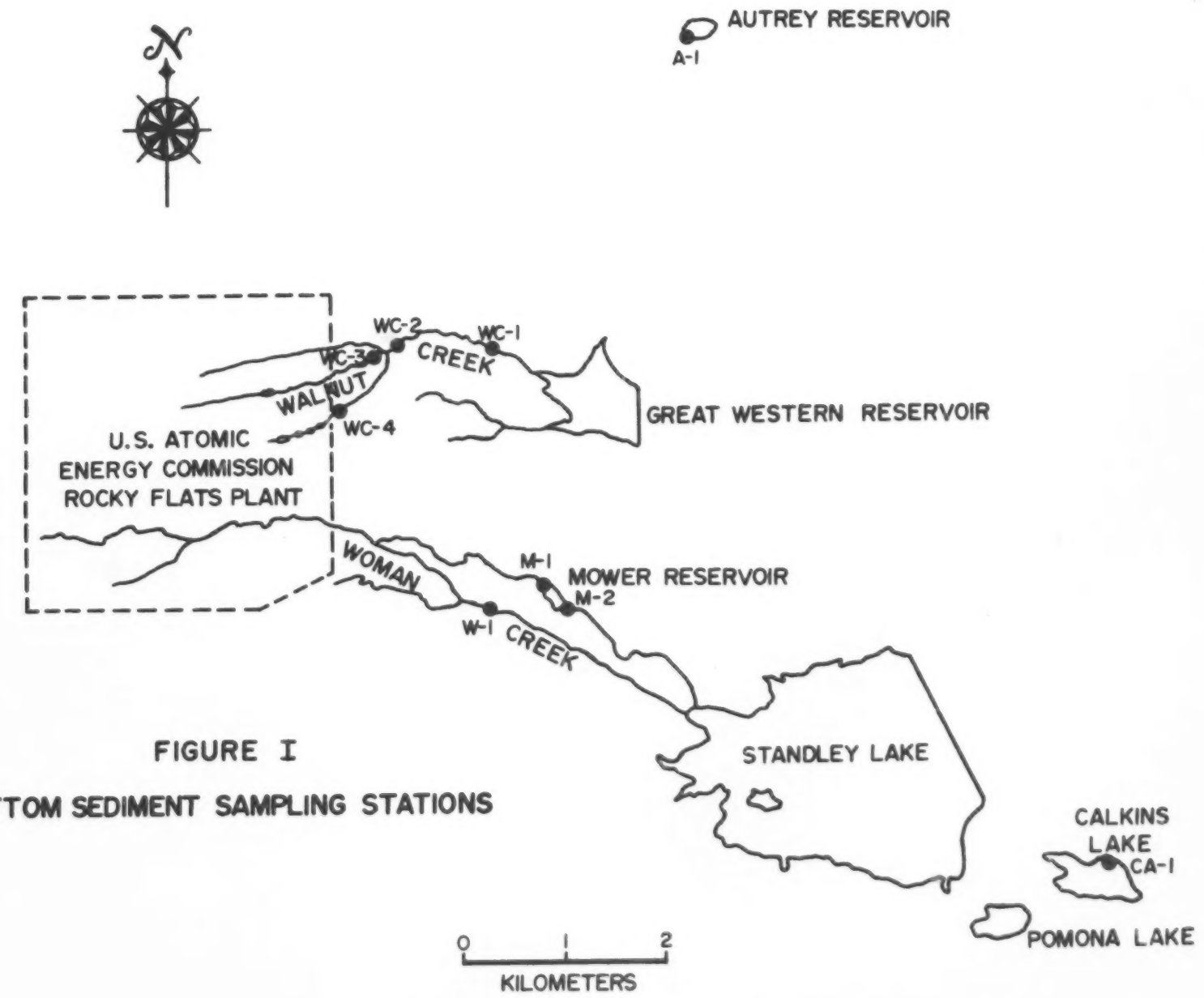

FIGURE I

BOTTOM SEDIMENT SAMPLING STATIONS

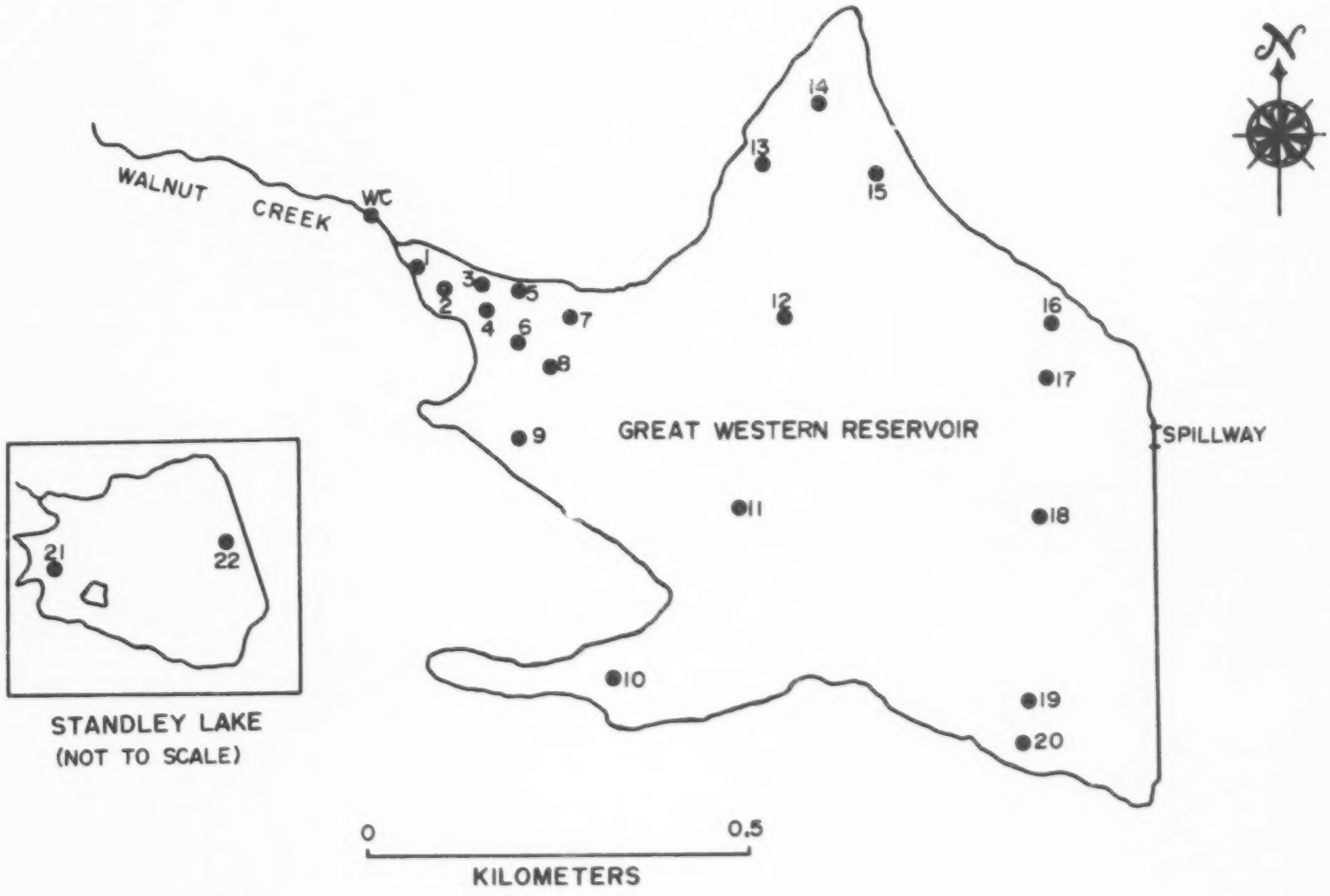

FIGURE II

SAMPLING STATIONS FOR BOTTOM SEDIMENT & BENTHIC INVERTEBRATES
GREAT WESTERN RESERVOIR & STANDLEY LAKE

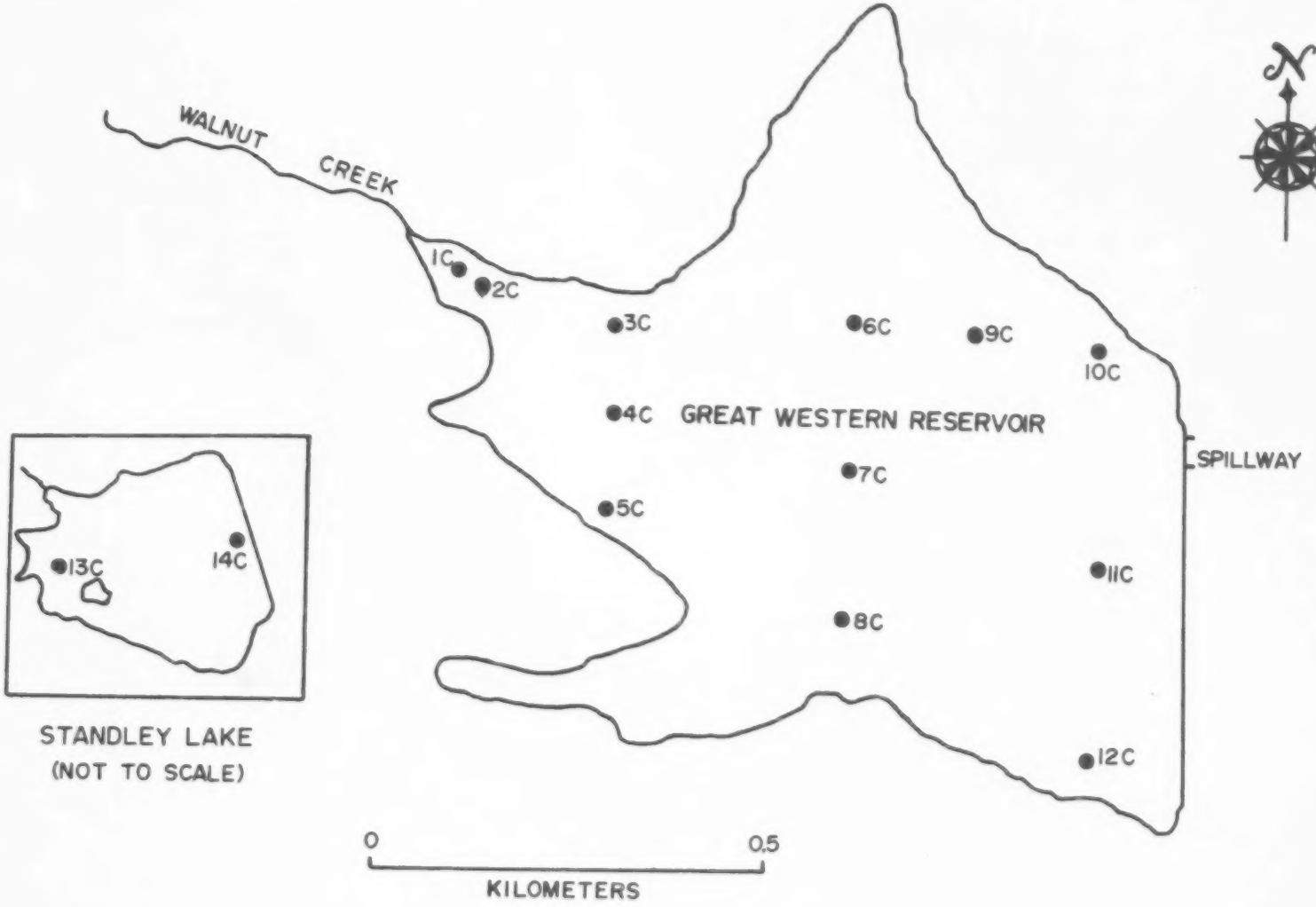

FIGURE III

SAMPLING STATIONS FOR CORE SAMPLES
GREAT WESTERN RESERVOIR & STANDLEY LAKE

TABLE I

SAMPLING STATIONS

Sample Type	Station Number	Description
Water	WC-1	Walnut Creek at Indiana Street
	-	Great Western Reservoir at dam face
	-	Standley Lake at dam face
Bottom Sediment	A-1	Autrey Reservoir; approximately 4 miles northeast of plant; Boulder County
	CA-1	Calkins Lake; north shore
	W-1	Woman Creek at Indiana Street
	M-1	Mower Reservoir at mouth of diversion ditch; west end
	M-2	Mower Reservoir; east end at dam face
	WC	Walnut Creek at mouth; inlet of Great Western Reservoir
	WC-1	Walnut Creek at Indiana Street
	WC-2	Main stem of Walnut Creek; 50 feet downstream of confluence of south fork with middle and north forks
	WC-3	Middle fork of Walnut Creek; 50 feet upstream of confluence with north fork
	WC-4	South fork of Walnut Creek at site boundary
	1-20 & 1C-12C	Great Western Reservoir
	21, 22, 13C, & 14C	Standley Lake
Benthos	1, 3-12, & 14-17	Great Western Reservoir
	21 & 22	Standley Lake
Fish	-	Great Western Reservoir; inlet and near dam face
	-	Standley Lake; inlet and near dam face

TABLE II

ELECTRO-FISHING - SPECIES OF FISH

Location	Species
Great Western Reservoir	
(A) Near inlet	Carp Northern Common Shiner Western White Sucker
(B) Near dam	Carp Green Sunfish Johnny Darter Northern Common Shiner Western White Sucker
Standley Lake	
(A) Near inlet	Carp Green Sunfish Large mouth Bass Northern Common Shiner Western White Sucker Yellow Perch
(B) Near dam	Black Bullhead Carp Green Sunfish Large mouth Bass Yellow Perch

RESULTS

Analytical results for water, bottom sediment, benthos, and fish samples are presented in TABLES III-VII. With the exception of water samples which were analyzed for both dissolved plutonium and uranium, radiological analysis was limited to the measurement of plutonium. Analytical procedures were the same as those described in the April 1971 report.(1)

Water

Plutonium and uranium in the water samples from Walnut Creek, Great Western Reservoir, and Standley Lake were essentially at baseline levels (TABLE III) and relatively unchanged from February 1970 levels. Dissolved uranium concentrations were less than 2.5 ug/l; typical of natural background in surface waters. Dissolved plutonium concentrations were less than 0.03 pCi/l which was considered in 1970 to be a baseline condition attributable to atmospheric fallout. In comparison with the February 1970 results, the only difference was the absence of an elevated uranium concentration in Walnut Creek (at Indiana Street) originating from plant waste discharges. However, this finding is not of great consequence since the elevated concentration observed in February was not large and could be questioned as a normal variation in background.

As a matter of general interest, surface runoff from rainfall was the reason for the high suspended solids concentration in Walnut Creek on the last day of sampling, September 25.

Bottom Sediment and Soil

In terms of a general comparison among stations sampled during both the February and September studies, plutonium levels in sediment collected in September (TABLE IV) were equal to or less than the corresponding February results. Considering the two impoundments assumed to be free of any impact from emissions from the Rocky Flats Plant - Calkins Lake and Autrey Reservoir, plutonium concentrations in sediment were 0.04 and 0.07 pCi/gram, respectively. These data were identical with the February results; reaffirming the conclusion that the baseline concentration in the bottom deposits of area surface waters was $\leq$ 0.10 pCi/gram. From the standpoint of absolute values, sediment from Mower Reservoir exhibited an apparent two-fold increase in plutonium between February and September. However, it seems likely that this was a pseudo-increase attributable to normal concentration variations and the relative imprecision of the soil sampling procedure, particularly in an area of low contamination.

Sharp reductions in the plutonium content of Walnut Creek sediment were observed in September. This is illustrated by the following comparative tabulation of data from the two studies conducted during 1970.

TABLE III

RADIOACTIVITY IN WATER SAMPLES

Station	Date	Suspended Solids (mg/l)	Plutonium Content of Suspended Solids (pCi/gram)(a)	Dissolved Plutonium (pCi/l)	Dissolved Uranium (µg/l)
Walnut Creek at Indiana Street (WC-1)	9/21-23 (Composite)	89	10	0.02	1.6
	9/24	53	15	<0.03	1.3
	9/25	390	3	<0.03	0.3
Great Western Reservoir at dam face	9/23-25 (Composite)(b)	13	<10	<0.02	2.1
Standley Lake at dam face	9/21-25 (Composite)	5	-	<0.01	2.4

(a) Dry weight basis
(b) No analysis for samples collected on 9/21 and 22.

TABLE IV

PLUTONIUM IN BOTTOM SEDIMENT SAMPLES

Station	Station Number	Water Depth (meters)	Plutonium Content (pCi/gram)(a)
Autrey Reservoir	A-1	-	0.07
Calkins Lake	CA-1	-	0.04
Walnut Creek			
South fork at site boundary	WC-4	-	0.14
Middle fork	WC-3	-	0.16
Main stem, below confluence with middle fork	WC-2	-	0.29
Indiana Street	WC-1	-	0.60
At mouth	WC	-	0.26
Great Western Reservoir	1	0.61	0.34
	2	0.92	0.86
	3	-	0.49
	4	0.92	0.57
	5	-	0.58
	6	-	0.34
	7	-	0.61
	8	3.05	0.52
	9	1.52	0.30
	10	1.98	0.25
	11	6.71	0.57
	12	4.88	0.08
	13	1.83	0.16
	14	-	0.15
	15	1.83	0.14
	16	4.57	0.10
	17	15.0	0.08
	18	16.5	0.31
	19	7.32	0.18
	20	1.68	0.12
Woman Creek at Indiana Street	W-1	-	0.20
Mower Reservoir			
West end	M-1	-	0.18
East end	M-2	-	0.18
Standley Lake	21	3.05	0.05
	22	19.2	0.21

(a) Dry weight basis

TABLE V

PLUTONIUM IN BOTTOM SEDIMENT CORE SAMPLES

Station	Station Number	Water Depth (meters)	Section Analyzed (inches)(a)	Plutonium Content (pCi/gram)(b)
Great Western Reservoir	1C	0.76	0-1	0.36
			1-2	0.58
			2-3	1.0
			3-5.25	0.43
	2C	0.76	0-1	0.44
			1-2	0.71
			2-3	0.26
	3C	2.14	0-1	0.38
			1-2	0.29
			2-3	0.19
	4C	1.37	0-1	0.10
			1-2	0.09
	5C	2.14	0-1	0.09
			1-2	0.04
			2-3	0.07
	6C	3.05	0-1	0.06
			1-2	0.06
	7C	7.77	0-1	0.27
			1-2	0.34
			2-3	0.06
			3-4	0.09
	8C	6.40	0-1	0.41
			1-2	0.29
			2-3	0.05
	9C	11.9	0-1	0.42
			1-2	0.26
			2-3	0.07
			3-4.25	0.07
	10C	11.0	0-1	0.09
			1-2	0.03
	11C	15.2	0-1	0.33
			1-2	0.27
			2-4	0.11
			6-7	0.41
			7-8	0.40
			13-14.5	0.06
	12C	5.49	0-1	0.08
			1-2	0.03
Standley Lake	13C	3.05	0-1	0.09
			1-2	0.11
	14C	19.2	0-1.25	0.28
			1.25-2.25	0.22
			2.25-3.25	0.13
			3.25-4.25	0.32
			7.25-8.25	0.12
			11.25-12.25	0.37
			12.25-14.75	0.18
			14.75-15.75	0.11

(a) The limits of the range are measurements in inches from the top surface of the core sample. No correction for compaction during sample collection (refer to Appendix B).

(b) Dry weight basis

TABLE VI

PLUTONIUM IN FISH

Station	Species	Number of Fish	Total Length (cm)	Organ	Sample Weight (grams)(a)	Plutonium Concentration (pCi/kilogram)(a)
Great Western Reservoir						
(A) Near inlet	Carp	15	45-85	Whole	52.0	<2.0
		3	283-364	Flesh	420	<0.3
			"	Liver	10.0	<20
			"	Bone	35.0	<4.2
			"	Roe	240	0.9
	Northern Common Shiner	153	30-81	Whole	171	9.6
	Western White Sucker	15	70-132	Whole	99	3.0
		8	140-272	Flesh	259	<0.6
			"	Bone	19.0	9.4
(B) Near dam	Carp	2	71	Whole	12.6	<7.0
		2	295&378	Flesh	318	<0.4
			"	Liver	5.0	<32
			"	Bone	27.5	<5.6
	Green Sunfish	32	31-48	Whole	27.0	<3.0
		56	49-76	Whole	196	1.0
		20	90-125	Flesh	146	<1.0
			"	Liver	6.0	30
			"	Bone	12.0	<14
		10	129-151	Flesh	163	<0.9
			"	Liver	8.0	<20
			"	Bone	19.0	<8.2
	Northern Common Shiner	50	30-75	Whole	79.6	3.7
	Western White Sucker	8	130-180	Flesh	115	<1.3
			"	Bone	10.0	<16
Standley Lake						
(B) Near inlet	Carp	2	329&390	Flesh	249	<0.7
			"	Liver	4.5	<37
			"	Bone	29.0	<5.8
	Green Sunfish	7	40-48	Whole	13.0	<13
	Largemouth Bass	7	61-90	Whole	45.0	<1.1
	Northern Common Shiner	9	55-74	Whole	27.0	<6.2
	Western White Sucker	1	83	Whole	158	<1.1
	Yellow Perch	25	46-70	Whole	50.0	<1.4
		4	106-130	Whole	72.0	<1.7
		6	171-231	Flesh	335	<1.1
			"	Liver	2.5	<73
			"	Bone	20.0	<8.4
(B) Near dam	Black Bullhead	1	165	Whole	125	<1.2
	Carp	4	335-368	Flesh	589	<0.3
			"	Liver	17.0	<9.9
			"	Bone	56.0	1.9
			"	Roe	32.0	14
	Green Sunfish	4	69-106	Whole	45.0	<3.4
		7	125-147	Flesh	95.0	1.8
			"	Liver	4.0	<18
			"	Bone	9.0	<19
		3	155-177	Flesh	89.0	<0.8
			"	Liver	4.0	<36
			"	Bone	13.0	32
	Largemouth Bass	3	43-59	Whole	+ Sample Lost +	
	Yellow Perch	1	106	Whole	15.0	<10
		5	160-192	Flesh	100	<1.5
			"	Liver	1.0	<160
			"	Bone	10.0	<17

(a) Live weight basis

TABLE VII

PLUTONIUM IN BENTHIC INVERTEBRATES

Station	Invertebrate	Sample Dry Weight (mg)	Plutonium Concentration (pCi/gram)(a)
Walnut Creek at Indiana Street	Blackflies	2247	0.07
	Caddisflies	3511	0.08
	Mayflies	225.4	<0.4
	Midges	92.6	<0.9
	Other	83.3	<1.0
	Crayfish	12.4	None Detected
Great Western Reservoir			
Sta. 1	Predominately Midges	6.4	55
	"	20.8	<5.0
	"	39.5	<2.0
Sta. 4	Midges and Sludgeworms	2.9	<28
		11.1	<7.0
Sta. 7	Midges and Sludgeworms	4.7	<17
		19.7	<5.0
Sta. 8	Midges and Sludgeworms	4.7	<17
Sta. 9	Midges and Sludgeworms	2.9	<27
		3.4	<23
Sta. 10	Midges and Sludgeworms	0.9	<85
		1.8	<43
Sta. 11	Midges and Sludgeworms	5.9	24
		9.0	<9.0
Sta. 12	Predominately Sludgeworms	10.3	<8.0
		12.1	<7.0
Sta. 13	Predominately Midges	3.0	<28
		8.6	<9.0
Sta. 15	Damselflies, Scuds, Midges, and Sludgeworms	6.1	<13
		11.3	<7.0
Sta. 16	Predominately Sludgeworms	10.3	<7.0
		12.9	<6.0
Sta. 17	Midges and Sludgeworms	3.5	<20
Sta. 18	Midges and Sludgeworms	2.0	<35
		3.6	<20
Sta. 19	Predominately Sludgeworms	19.8	<4.0
	Midges	21.5	4.0
Sta. 20	Mayflies, Caddisflies, Scuds, Midges, and Sludgeworms	3.4	<20
		13.3	<5.0
Standley Lake			
Sta. 21	Midges and Sludgeworms	2.6	<33
		22.8	6
Sta. 22	Predominately Sludgeworms	9.5	<9.0
		18.7	<5.0

(a) Dry weight basis

Walnut Creek Station	Plutonium Concentration (pCi/gram)	
	February	September
South fork at site boundary	3.51	0.14
Middle fork	0.50	0.16
Main stem, below confluence with middle fork	3.41	0.29
Indiana Street	0.92	0.60
At mouth; inlet to Great Western Reservoir	1.75	0.26

These data indicated scouring of contaminated sediment from the creek bed and/or coverage of contaminated zones by less contaminated soil washed into the creek without reaccumulation to previously observed maximal levels by mass transport from the aqueous phase. Assuming that the routine discharge of plutonium-bearing liquid wastes is the major source of sediment contamination, the reduced September concentrations were apparently the result of high flow shortly before the collection of samples. Unfortunately, flow data required for a truly meaningful interpretation of the limited sediment data are not existent. In the case of Woman Creek, no significant difference was observed between the February and September results - 0.23 and 0.20 pCi/gram, respectively.

The results for "dredge" samples and the top one-inch sections of core samples showed that nearly the entire bed of Great Western Reservoir contained plutonium at concentrations in excess of the baseline value, $\leq$ 0.10 pCi/gram. Plotted in FIGURES IV and V, only the extrapolated shaded areas represent bottom deposits containing 0.10 pCi/gram or less of plutonium. The area or sector of greatest contamination appeared to be the central section of the reservoir (inlet to dam) with maximum concentrations near the inlet. In the inlet area, the maximum concentration in the top one-inch section was 0.86 pCi/gram (Station 2) with an average concentration of 0.50 pCi/gram for Stations 1-8 and 1C-3C. Sediment samples from the northern arm (Stations 13, 14, and 15) showed plutonium concentrations only about 50% higher than the baseline value - average concentration of 0.15 pCi/gram for the three stations. Bank sloughing was observed in this arm.

Core samples from Great Western Reservoir showed that the thickness of deposited plutonium-contaminated sediment was 2 inches or more at all locations (TABLE V). Near the face of the dam in the deep-water area, plutonium contamination on the order of four times the baseline level was found at a sediment thickness of 7 to 8 inches (Station 11C). At Station 10C, adjacent to Station 11C in the deep-water area, baseline concentrations were obtained from the core sample. However, these findings are consistent when the differences in bottom conditions are taken into account. Unlike Station 11C where the layer of "black" sediment was 8" thick (compacted in the core tube),

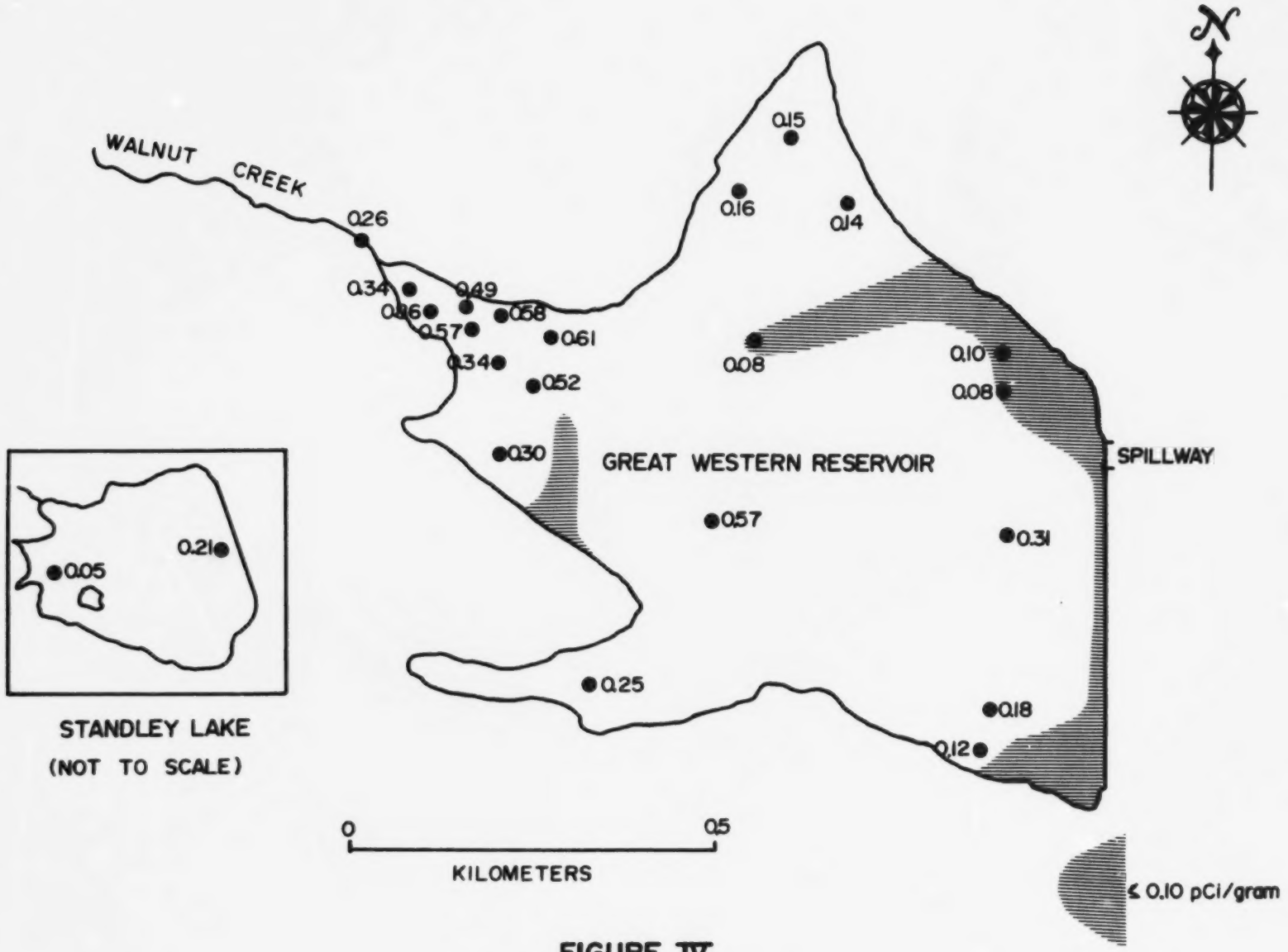

FIGURE IV

PLUTONIUM (pCi/gram) IN BOTTOM SAMPLES
GREAT WESTERN RESERVOIR & STANDLEY LAKE

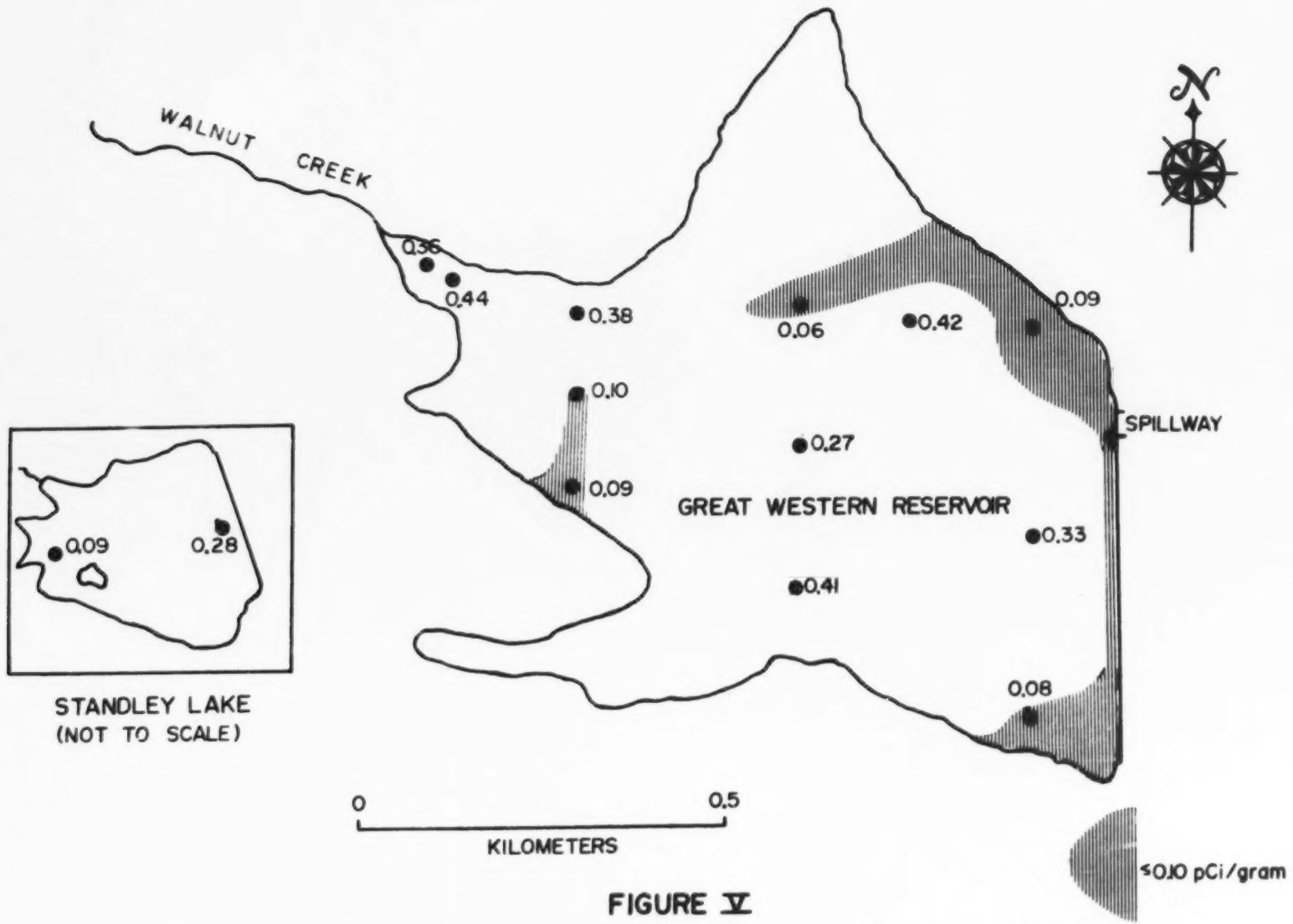

FIGURE V

PLUTONIUM (pCi/gram) IN THE TOP ONE-INCH SECTION OF CORE SAMPLES

GREAT WESTERN RESERVOIR & STANDLEY LAKE

only the top one inch section of the core collected at Station 10C was of similar composition. Below one inch, clay was found at Station 10C. The finding that plutonium contamination is not restricted to the surface layer of bottom sediment suggests a contamination source of some duration; presumably, the continuously occurring discharge of liquid wastes from the Rocky Flats Plant.

Dredge and core samples from the west end of Standley Lake near the mouth of Woman Creek (Stations 13C and 21) showed baseline concentrations of plutonium (TABLES IV and V; FIGURES IV and V). In contrast, samples collected at Stations 14C and 22 - east end of the lake just offshore of the dam in the deep-water area, contained plutonium in concentrations on the order of two to three times baseline. Furthermore, the results for the several sections of the core sample showed that plutonium contamination was not limited to the surface, but extended to a thickness of approximately 12 inches (compacted in the core tube). Since plutonium-bearing liquid wastes are not and have not been discharged to Woman Creek, the origin of plutonium-contaminated sediment in Standley Lake would have to be contaminated soil transported and deposited in the lake by runoff. Although this is a plausible source for the contamination of the surface layer of sediment, it is not a good explanation for the finding of plutonium contamination to a thickness of several inches. To verify the existence of significant zones of plutonium-contaminated sediment in the lake, or disprove as the case might be, additional monitoring of a scope similar to that used for Great Western Reservoir will be required. Until this effort is undertaken, the results for Stations 14C and 22 will be subject to question on the basis of possible sample contamination.

Similar to the findings for bottom sediment samples from area surface waters, the two soil samples showed substantially lower plutonium concentrations in comparison to those collected from the same general locations in February.

Location	Plutonium Concentration (pCi/gram) February	September
Grazed area to the southeast of the road culvert conveying Woman Creek under Indiana Street	2.42	0.64
Ungrazed area near the southeast corner of Great Western Reservoir	0.42	0.14

Fish and Benthos

Information presented in the literature review of Olafson and Larson(2)

on the biology and environmental persistance of plutonium leads one to the conclusion that plutonium entering the Walnut Creek - Great Western Reservoir system as the result of liquid waste releases ultimately accumulates in the reservoir sediment with very little transfer to and cycling in aquatic biota. Among the conclusions reached by Olafson and Larson, the following are pertinent to the Rocky Flats "situation."

(1) Plutonium is absorbed by plants growing on contaminated soil to an infinitesimal degree, although it may be found as an external contaminant on vegetation.
(2) Ingested plutonium is absorbed and retained in animal tissues to only a very small degree.
(3) Based on animal tissue assays, very little plutonium gains entry into mammalian systems.

In animals, ingested plutonium concentrates in bone and liver tissue. There is also concentration in reproductive tissue.

The results for benthos and fish (TABLES VI and VII) generally showed that there was no significant accumulation of plutonium in the biota of Great Western Reservoir and Standley Lake. As evidenced by the preponderance of "less than" results, small sample size, particularly in the case of benthos samples, prevented the conduct of analyses with the high degree of analytical sensitivity required for definitively determining absolute concentrations. Excluding the five positive results, the "best" detection limit for benthos samples was about 40 pCi per kilogram (live weight)(a) whereas the desired sensitivity was within the range of 0.1 to 1.0 pCi/kg. Furthermore, considering sample size, only the positive results for blackflies and caddisflies from Walnut Creek at Indiana Street should be given credence as valid, absolute concentrations.

Although the analysis of fish samples also produced few absolute concentrations, larger sample sizes - gram amounts instead of milligrams - enabled the conduct of analyses with precision consistent with the range of expected low concentrations (refer to TABLE VIII - plutonium in foodstuffs reported in 1959 by the U.S. Atomic Energy Commission). Considering edible tissue (flesh), the plutonium concentrations in all species from both impoundments were less than 2 pCi per kilogram (live weight). Hence, human consumption of these fish would be insignificant from the standpoint of resultant radiation dose because the daily intake limit for the general public, as recommended by the National Committee on Radiation Protection[3], is approximately 3700 pCi of plutonium. One finding of interest was the apparent accumulation of plutonium in carp roe. Although beyond the scope of this report, this finding raises the question of a possible genetic effect on fish.

(a) Calculated on the basis of an assumed moisture content of 90%.

TABLE VIII[a]

PLUTONIUM CONCENTRATIONS IN VARIOUS FOOD ITEMS AND PLANTS

Item	Plutonium-239 Concentration (pCi/kilogram)
Rain	0.18
Alfalfa ash	430 to 800
Milk	0.16
Wheat ash	130 to 670
Swordfish	0.34 to 1.0
Pork liver	0.56 to 2.7
Beef meat	0.19 (meat of chuck steak) 180 (fluid)

(a) TABLE 4 in Reference 2 (data from U.S. Atomic Energy Commission, Quarterly Statement on Fallout in "Fallout from Nuclear Weapons Tests. Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy, Congress of the U.S., May 5-8, 1959," pp. 2188-2198, U.S. Government Printing Office, Washington, D.C., (1959)).

Aside from radiological considerations, benthos and plankton sampling showed the presence of pollution tolerant organisms in both Great Western Reservoir and Standley Lake; indicative of enriched or eutrophic conditions. In the case of Great Western Reservoir, the contributing polluton sources are domestic-type wastes from the Rocky Flats Plant and agricultural runoff whereas only the latter is the source to Standley Lake. The pollution biology aspects of the field study are presented in detail in Appendix A.

SUMMARY

The September 1970 field study produced the following significant findings.

(1) Almost tne entire bed of Great Western Reservoir was covered with sediment containing plutonium in excess of the estimated baseline concentration, $\leq$ 0.10 pCi/gram. The thickness of the layer of plutonium-contaminated sediment was 2 inches or more at all such sampling stations. The maximum concentration of approximately 1.0 pCi/gram was obtained at the inlet area of the impoundment.

(2) Limited sediment sampling in the deep-water area of Standley Lake indicated possible sectors of plutonium contamination attributable to past emissions from the Rocky Flats Plant.

(3) Fish and benthos from Great Western Reservoir and Standley Lake did not show significant accumulation of plutonium. In all species of fish, the concentration in flesh was <2 pCi/kilogram-live weight. At this low concentration, human consumption at an abnormally high intake rate of one kilogram per day would be inconsequential in terms of radiation dose.

In that this study was the initial comprehensive effort at determining plutonium concentrations in the biota and sediment of Great Western Reservoir and Standley Lake, additional monitoring will be necessary to determine the representativeness of the specific results as maximum, steady-state values or "points" on curves showing increasing or decreasing trends.

REFERENCES

(1) Environmental Protection Agency, "Radioactivity levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado, 1970," Radiological Activities Section, Division of Technical Support, Water Quality Office (April, 1971).

(2) Olafson, J. H., and Larson, K. H., "Plutonium, Its Biology and Environmental Persistence," in "Radioecology," edited by V. Schultz and A. W. Klement, Jr., pp 633-639, Reinhold Publishing Corporation, New York, New York, and The American Institute of Biological Sciences, Washington, D. C., (1963).

(3) National Committee on Radiation Protection, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," U.S. Department of Commerce, National Bureau of Standards Handbook 69, U.S. Government Printing Office, Washington, D. C. (1959).

APPENDIX A

BIOLOGICAL STUDY OF GREAT WESTERN RESERVOIR

A biological study was conducted on Great Western Reservoir during the week of September 21 to 24, 1970. Objectives of the study were to determine: a) effects on the reservoir of domestic sewage discharged to Walnut Creek, a tributary to the reservoir, from the Rocky Flats Plutonium Plant, and b) the existing levels of plutonium in the sediments, benthic invertebrates, and fish in the reservoir.

In a lake the clean water benthic community is usually composed of many kinds of organisms, each kind being few in number. When domestic sewage is discharged to a lake, the number of kinds of benthic organisms are reduced and the remaining organisms are able to increase in number. A lake receiving domestic sewage or runoff from surrounding agricultural areas may have an oxygen consuming layer of decomposing organic material. Such a layer is caused by either an inflow of suspended organic matter which settles to the bottom or by the contribution of large amounts of nutrients which cause an increase in the plankton population during the spring and a resultant die-off and settling of the plankton each fall.

The water layer above a bottom of decomposing organic material is usually low in dissolved oxygen and the bottom material supports only small numbers of pollution tolerant organisms.

Methods

Samples of the benthic invertebrate populations were obtained from Walnut Creek and the reservoir with either a Petersen dredge or Eckman dredge. Sampling stations are depicted in FIGURE II. Benthic invertebrates were collected from all stations except Stations 2, 3, 5, 6, and 14. Dredge samples were sieved through a U.S. Standard No. 30 sieve and material retained on the sieve was preserved in five per cent formalin. All samples were picked and invertebrates identified in Cincinnati, Ohio.

Short five-minute tows were made with a plankton net near the inlet and middle of Great Western Reservoir and near the middle of Standley Lake. The concentrated plankton samples were examined to determine the qualitative composition of the algal populations in each water body.

Results

The bottom sediments in Great Western Reservoir did not support large numbers of organisms (TABLE A-I and FIGURE A-I). Only in an area extending from the inlet of Walnut Creek and the offshore areas near the dam were the numbers of organisms large enough to merit mention (FIGURE A-I).

TABLE A-I

TOTAL NUMBER AND KINDS OF BOTTOM ORGANISMS COLLECTED FROM GREAT WESTERN RESERVOIR AND STANDLEY LAKE

	Walnut Creek	Great Western Reservoir														Standley Lake	
		1	3	4	5	6	7	8	9	10	11	12	14	15	16	17	33	34
Mayflies																		
Baetis sp	272	Q																
Caenis sp	5						Q											
Caddisflies																		
Cheumatopsyche sp	1924	Q					Q											
Neotrichia sp	12																	
Damselflies																		
Odonata		Q										Q						
Scuds																		
Hyalella sp	22						Q					Q						
Midges																		
Glyptotendipes sp							Q					Q		Q		7		
Cricotopus sp	411						Q					Q						
Spaniotoma sp	10																	
Chironomus sp	2	65	7	10	7	21	3			Q	4	Q	34	3	24	26		31
Procladius sp							1											
Cryptochironomus sp							11			2		5	Q					
Tanytarsus sp							8			2		3						
Biting Midges																		
Stilobezzia sp	10	Q																
Phantom Midge																		
Chaoborus sp						1		3	4								Q	
Mosquito																		
Culicinae					Q													
Blackflies																		
Simulfidae	1671																	
Snails																		
Physa sp	3																	
Sludgeworms	15	24	3	14	24	74	5	2	Q	72	46	19	2	10	5	19	16	10
Crayfish	2																	
TOTAL NUMBER	4359	89	10	24	31	96	28	5	4	76	50	27	36	13	29	52	16	41
TOTAL KINDS	13	6	2	2	3	3	10	2	2	4	2	8	3	3	2	3	2	?

Q = Organisms not collected quantitatively, arbitrarily given value of 1 for computing number of kinds.

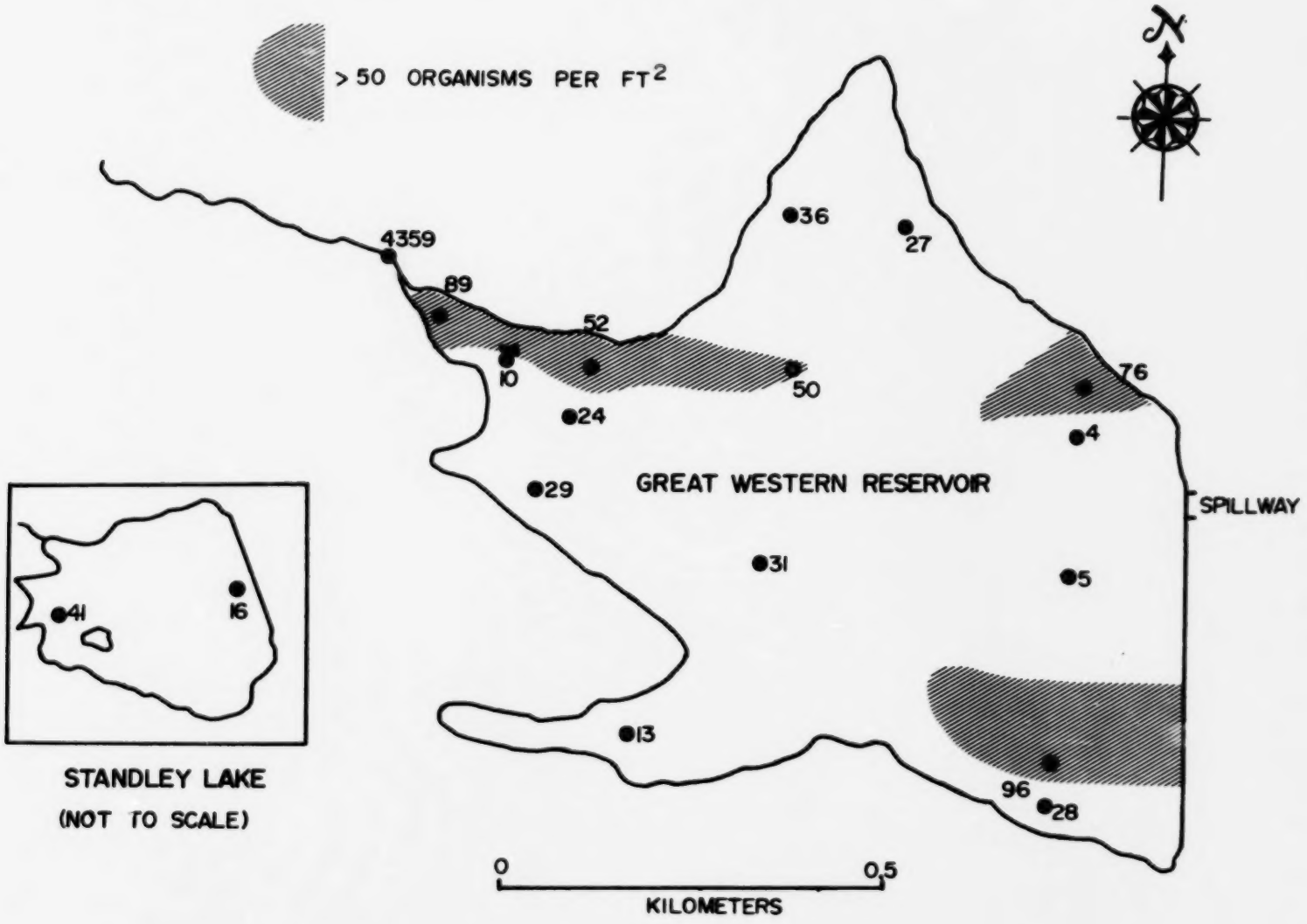

FIGURE A-I

DISTRIBUTION OF BOTTOM ORGANISMS PER SQUARE FOOT

GREAT WESTERN RESERVOIR & STANDLEY LAKE

The inlet (Station 1) supported a diverse population of organisms that received nutrients from Walnut Creek. The creek supported an enriched community of 13 kinds of organisms numbering 4359 per square foot; an indication that nutrients discharged from the Rocky Flats Plutonium Plant affect the benthic community immediately upstream from the reservoir. At the inlet or upper end of the reservoir (Station 1) the population of benthic organisms was composed of six kinds with a total number of 89 organisms per square foot; twice as many organisms per square foot as collected in the upper end of Standley Lake (Station 21) which is not reported to receive domestic sewage.

Great Western Reservoir had low numbers of benthic organisms at all stations except Stations 12, 16, and 19, where the benthic community was predominately sludgeworms numbering 74, 72, and 46 square foot, respectively. The larger numbers of sludgeworms at these stations as opposed to the other areas of the lake (TABLE A-I) were probably due to nutrients received from Walnut Creek. Other areas of the reservoir that would have been affected by nutrients in runoff water, and not domestic waste, such as Stations 10, 13, and 15, did not support large numbers of sludgeworms. The deep water area of the Great Western Reservoir represented by Stations 17 and 18 supported only small numbers of pollution tolerant midges and sludgeworms (TABLE A-I, FIGURE A-I). The reduced number of organisms in this area of the reservoir was caused by the presence of a layer of black decomposing organis material on the bottom. Cores of the bottom material revealed 9 to 21 inches of black sediment covering the bottom. Bottom samples had a slight hydrogen sulphide odor. Since a similar black organic material was collected at Station 22 in Standley Lake, the assumption must be made that both lakes receive nutrients and organic material from land runoff and such material settles in the deeper areas where it decomposes. In the case of Great Western Reservoir, the nutrients received from Walnut Creek add to the effects of nutrients from agricultural drainage, thus affecting a larger area of the reservoir.

In the plankton samples from Great Western Reservoir, filter-clogging organisms such as Melosira sp. abundant, and taste and odor organisms such as Staurastrum sp. and Ceratium sp. were present, indicating possible water treatment problems. Pollution tolerant Microcystis sp. was also present, and indication that the reservoir water contained excessive amounts of nutrients. Standley Lake phytoplankton were predominantly composed of the pollution tolerant algae Microcystis sp. and Anabaena sp., indicating the lake has received enough nutrient from agricultural runoff to become highly enriched or eutrophic.

APPENDIX B

MEASUREMENTS OF CORE SAMPLES

Station	Station Number	Penetration of Core Sampler (inches)	Total Length of Core Sample (inches)
Great Western Reservoir	1C	5.3	5.3
	2C	6	5.5
	3C	7	5
	4C	5	4.5
	5C	6	5
	6C	7.5	6.5
	7C	24	8.5
	8C	10.5	7.3
	9C	19	5.3
	10C	7.5	4.8
	11C	47	15
	12C	5	4
Standley Lake	13C	7.5	4.5
	14C	43	16.8